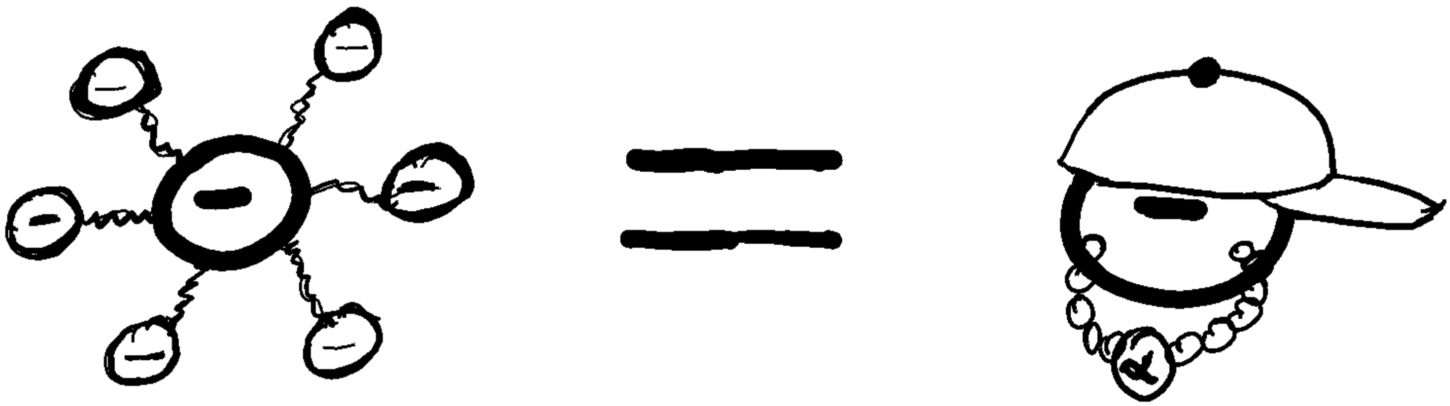
Many Body Physics

Everybody's physics



Quasiparticles – like particles, but dressed

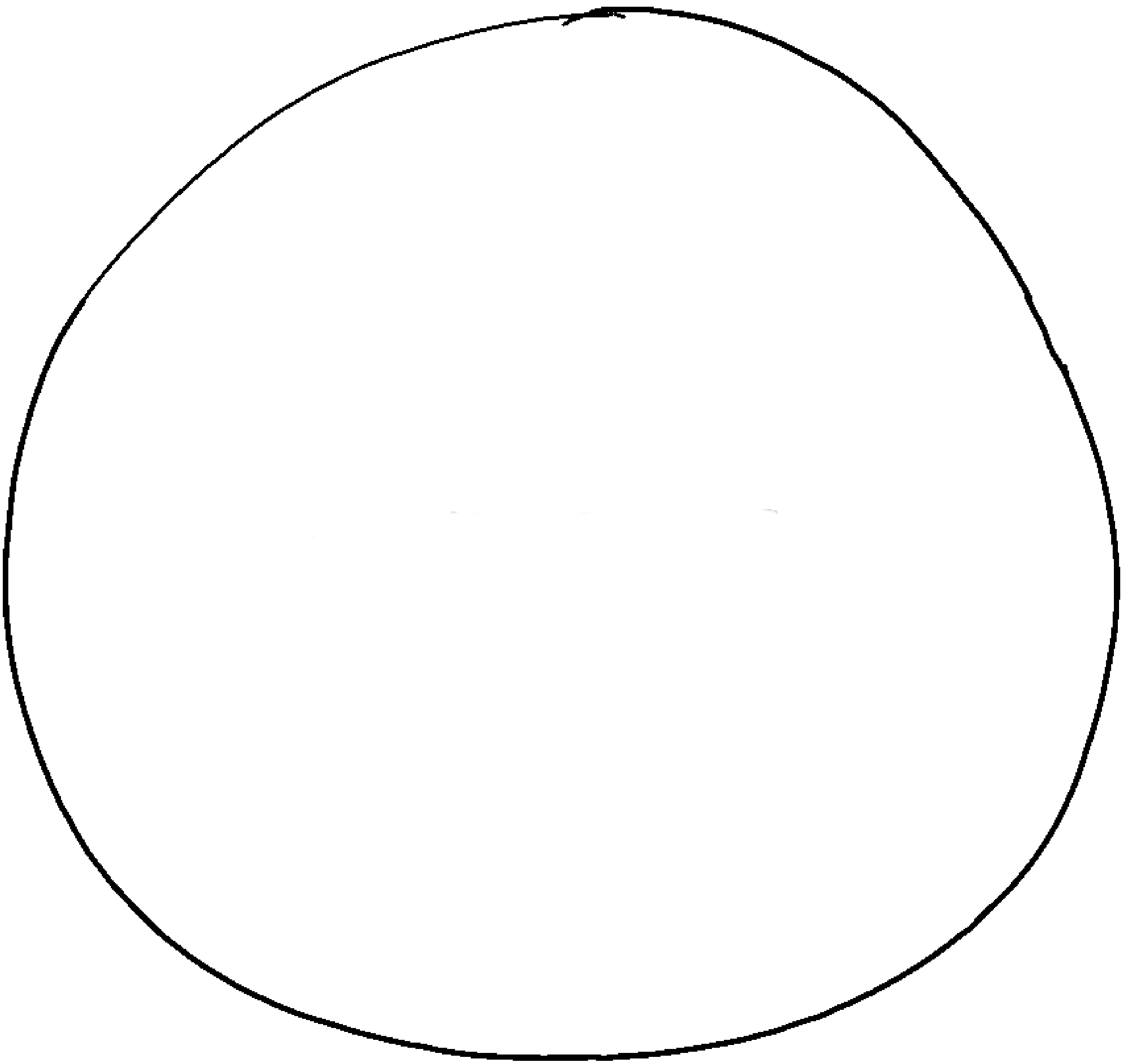
Most people know that the concept of a "particle" is a pretty important in fundamental physics (the latest success being the discovery of the "Higgs" particle in 2012) – but have you ever heard of **QUASIparticles** before?

What makes the notion of quasiparticles an important concept in the field of many body physics? Most properties of all "normal" materials around us can be described and even quantitatively predicted by using the picture of of quasiparticles. For example, whether a material conducts electricity or not is directly linked to the properties of the material's quasiparticles. The importance of understanding their properties can't be understated: it's the quasiparticle properties of the semiconductor silicon which make it possible to build computers such as the one you are using right now to read these lines.

The formation of quasiparticles is a **many-body** effect, that means that many fundamental constituents of matter work together to create a bigger whole which again looks like a particle. This makes explaining them from basic principles harder, but also more exciting (and calculating their properties gives people like me a job).

What is a particle?

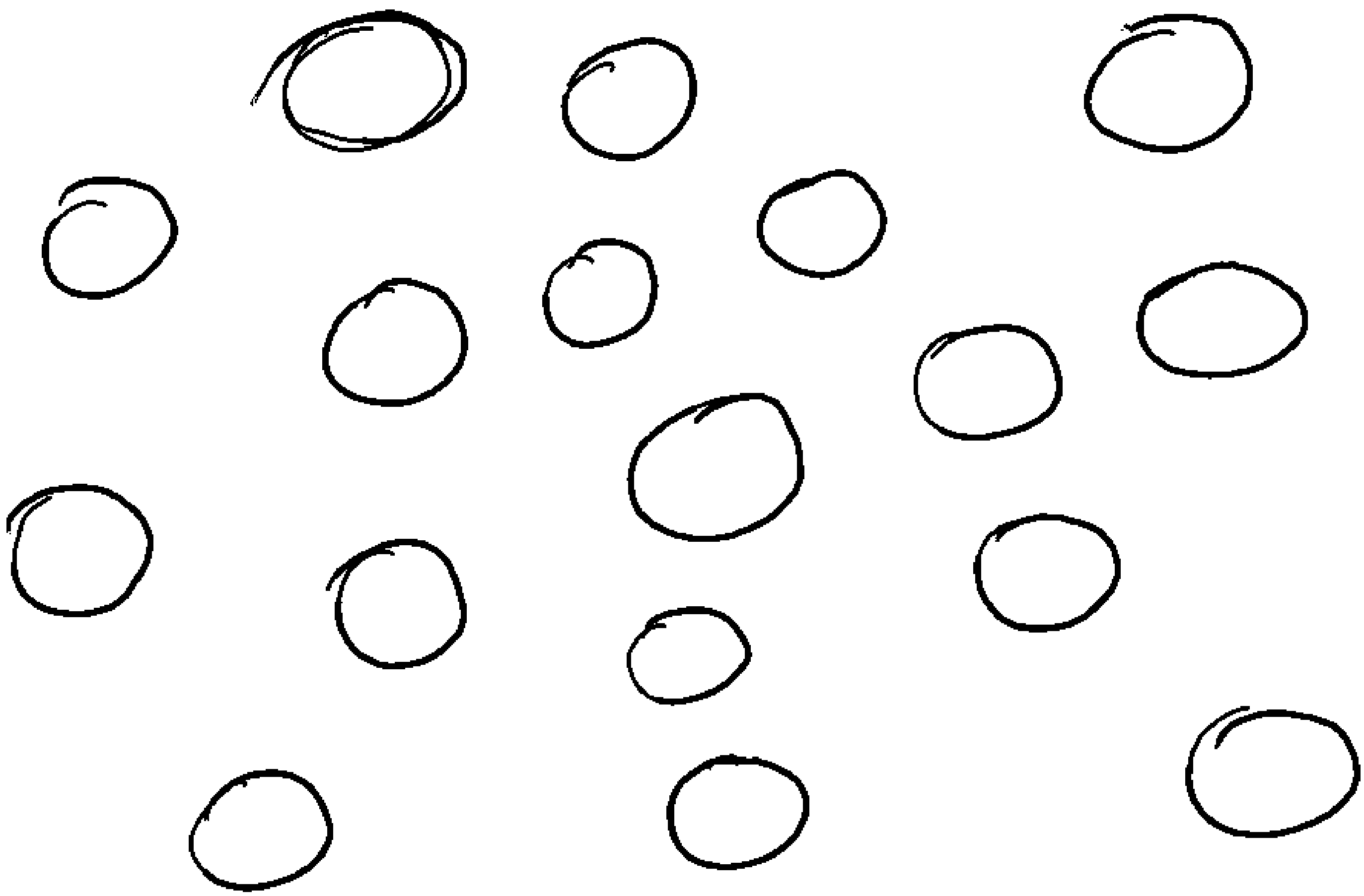
Let’s start simple and define what we mean with a particle and come back to the “quasi” bit later. A particle is a fundamental constituent of matter, so we picture them as a blob .



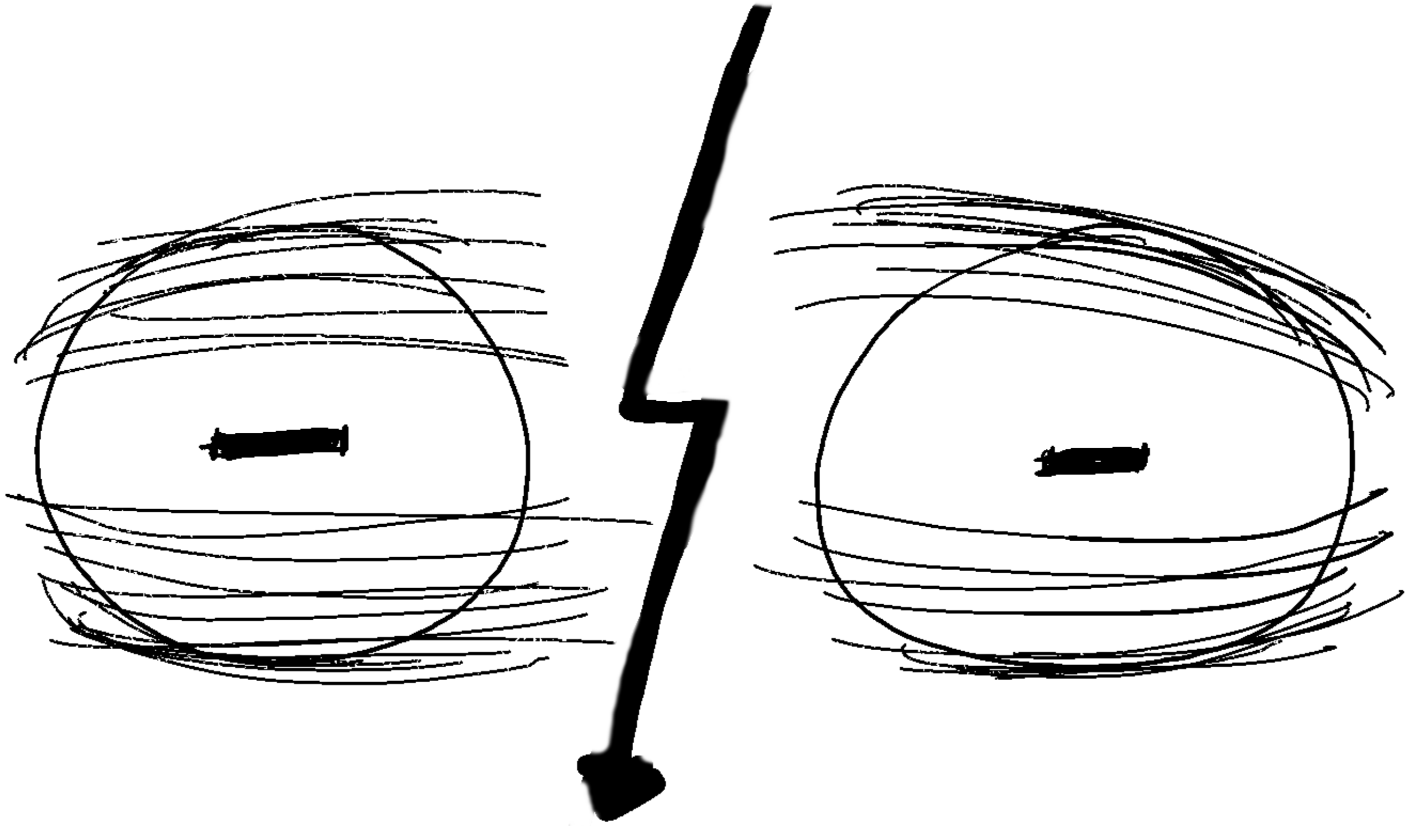
Examples for this are the electrons in a solid or atoms in a gas, but also all particles in the standard model of particles physics (our current most fundamental theory of nature). If you want, people are also some kind of big particle (and depending on their appetite more or less resemble the picture above). Particles have some characteristic properties, such as electric charge (which determines whether or not it interacts via the electric force with other particles) and mass (which roughly determines how quickly a particle propagates through the medium). Most importantly, they are *stable,* i.e. they do not decay into something else but stay as they are. This is why they are also often called the *fundamantal* particles because they cannot be split up into other constituents. In that sense they are the modern day physics variant of what the old Greeks called ἄτομος (átomos, undividable).

Particles are social – they interact

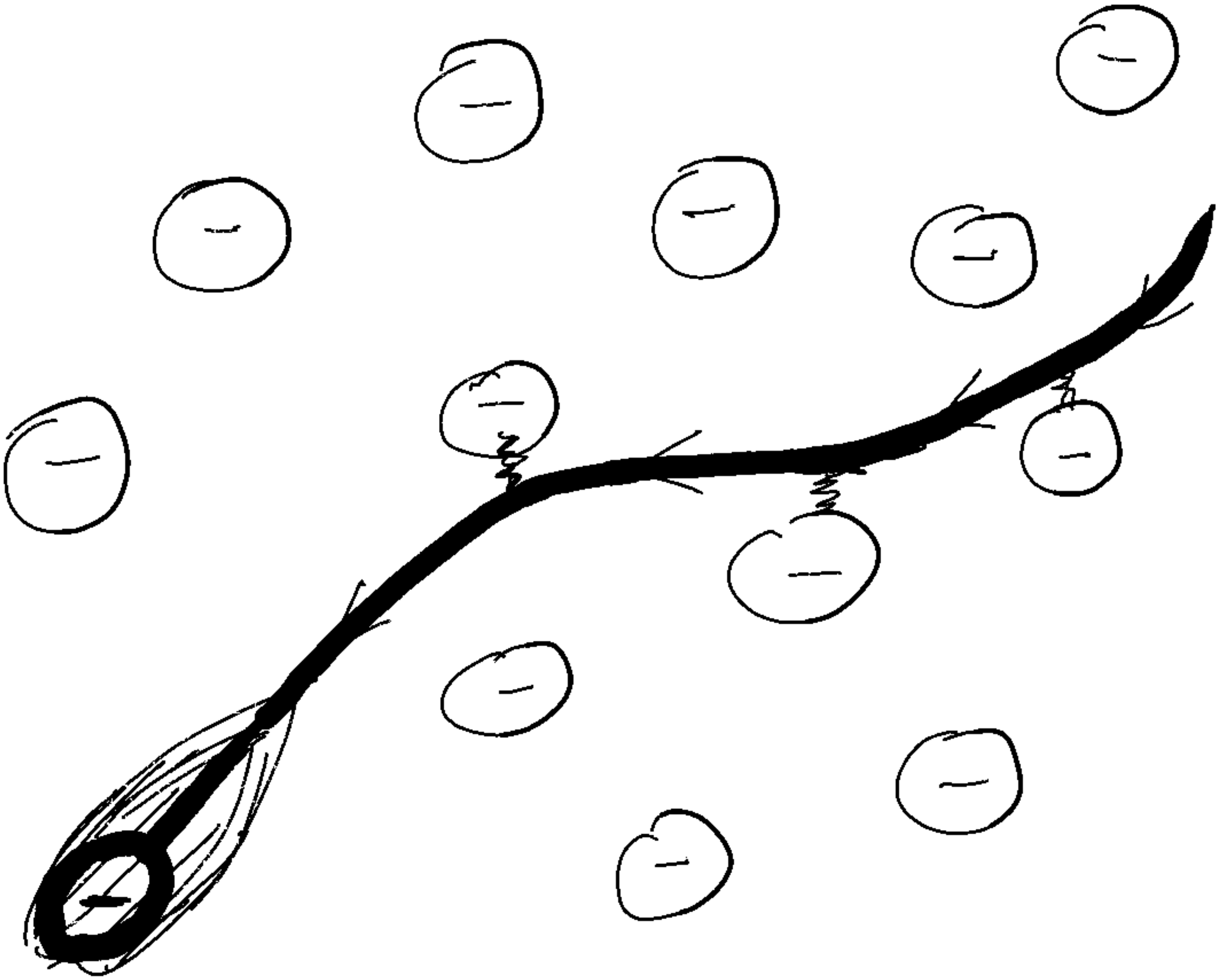
Now, particles are usually far from being loners, they usually are surrounded by many friends.



In the picture above it seems like those particles are not very sociable, or, more physically speaking, they are not interacting. In a real system, however, particles do talk to each other and therefore interact. In a solid, for example, electrons repel each other because of their (negative) electric charge. Again, people are a quite useful analogy here: they simply interact via chatting, which can lead to attraction or repulsion depending whether their "charges"/interests match or not.



It is easy to imagine that these interactions won't leave the picture of freely moving particles in a medium unharmed – a typical path of a particle might now look like this

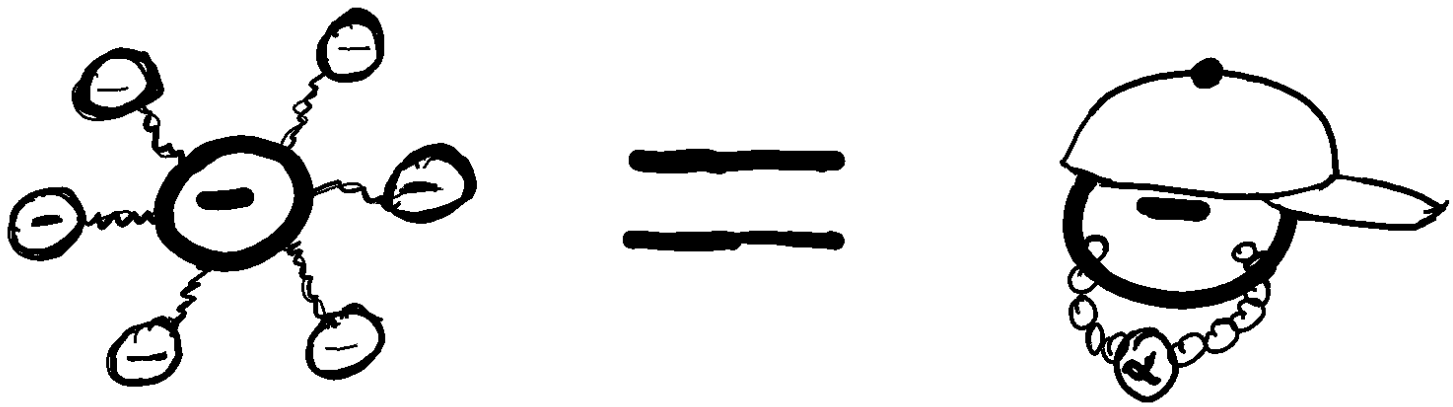


All of those deviations in the path of the particle are interactions with some other particle it meets on the way. You can imagine a very sociable person walking through a room with many people they know – a lot of chatting will be done on the way through the crowd and the direction of the path will always be altered.

Particles get dressed by interactions

If we look from far away and try to blend out all the other particles, it looks as if there was a far heavier (i.e. slower) particle moving through the medium. To see this look again on the picture above – the moving particle didn't take the most direct way, but some altered non-direct one. Therefore the time it took from entry to exit of the area we look at in the picture is longer and therefore the effective speed is slower.
When blending out all the other particles, we can effectively describe the "slower" version of the particle as a "dressed" particle (yes, this is really the technical term for that!) and so the description of the system

in terms of a sea of particles interacting with each other and making each other slower is equivalent to a description in terms of freely moving "dressed" particles.

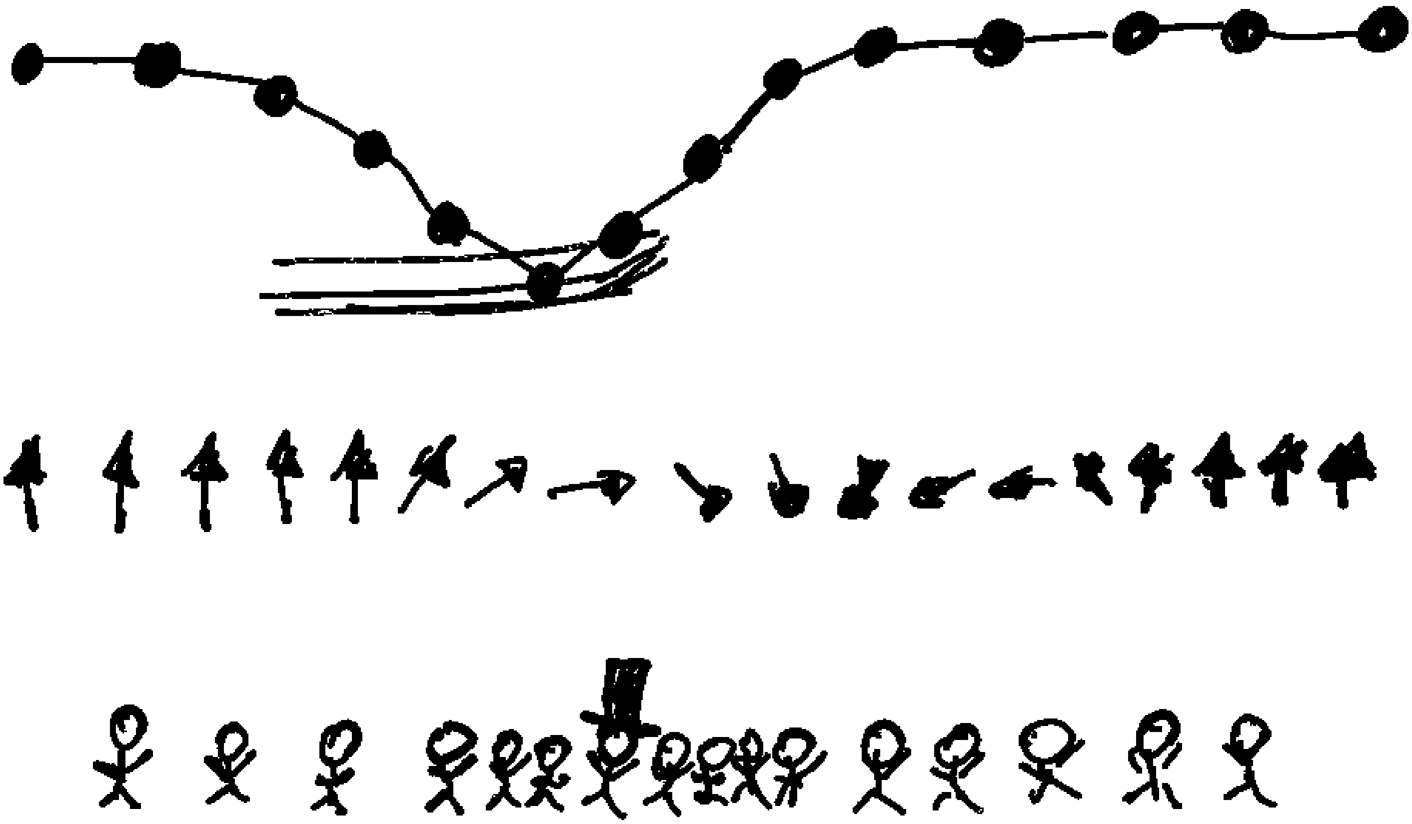


You may have already guessed it – those dressed particles are nothing else than the "quasiparticles" we were looking for in the beginning. "Quasi" because they don't correspond to any physical, fundamental particles (like the electrons) but rather consist out of many particles interacting with each other to form one effective unit which we can identify as a quasiparticle. It is therefore a true **many-body effect**.

Another way to understand this concept of a quasiparticle is by again resorting to our people-in-a-room picture: the person walking through the room takes longer to cross the room by chatting to all these people. We could however blend out all the other people in the room and just ascribe a smaller velocity to the person crossing the room, describing her as a "quasiperson".

Quasiparticles are ubiquitous around you

You may fairly ask "this sounds all well and nice but what can we do with that quasiparticle picture?". And the answer is: A lot of things, almost any material in your immediate surroundings can be understood in terms of some sort of quasiparticle! The properties of magnets (for example in the transformer with which you charge your phone) follow from the quasiparticles propagating in them (the magnons). You yourself can also create quasiparticles at will by opening your mouth and making some sort of sound! This creates excitations travelling through the air and their basic constituent quasiparticles are called phonons. You may also have heard of the "Higgs" particle before, which was found just a couple of years ago at the large hadron collider in Geneva. It is exactly through interacting with the Higgs particles that some of the otherwise massless fundamental constituents of nature acquire a mass – they effectively become quasiparticles.



A few examples for quasiparticles: A phonon propagating through a chain of atoms (for example in a solid), a magnon propagating through a magnet, a VIP propagating through a chain of people

For us many-body physicist the story however doesn't end there. The really interesting bit starts, when this straightforward quasiparticle picture presented here breaks down. When does this happen? For example when the interactions between particles are not repulsive (as I described here) but attractive. Electrons in solids can then for example form weakly bound pairs, which form the base of the explanation for how superconductors work – materials, which can conduct electricity without any energy loss. Needless to say that this is of current interest for research – imagine being able to transfer energy from any place in the world to any other (without loss)! But this is a topic for another time…

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Thoughts on "Quasiparticles – like particles, but dressed"

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See also: Theodore N Tomaras, Nicolaos Toumbas, IR dynamics and entanglement entropy.
https://arxiv.org/abs/1910.07847
https://en.wikipedia.org/wiki/Quasiparticle
https://www.sciencealert.com/quasiparticles

NOTE
I suggested gravitational quasiparticles at
http://chakalov.net/#August_17_2017
The current theory of gravity (p. 9 in
http://chakalov.net/text.pdf)
does not admit gravitational superposition.
We need quantum gravity:
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